APPENDIX A. OVERVIEW OF BROADBAND SPECTRUM SURVEYS

A.1 Introduction

Procedures for conducting a broadband spectrum survey using the RSMS are outlined in this Appendix. Site selection factors, significant measurement system parameters, and hardware and software configurations developed for the surveys are described. Measurement system response to various types of signals is described in Appendix B. Detailed information on the system hardware (including the vehicle, instrumentation, antennas, and receiver front-end), measurement software, and other measurement capabilities are provided in Appendices C and D. RSMS calibration theory and application are described in Appendix E.

A.2 Survey Site Selection

A successful spectrum survey (also called a site survey) requires careful selection of a measurement site. Maximum signal intercept probability and minimum logistic problems are the first considerations when locating a site for an RSMS spectrum survey.

The primary signal intercept factors are 1) maximum line-of-sight coverage to increase the probability of weak signal reception, such as transmissions from mobile units; 2) limited numbers of nearby transmitters to prevent intermodulation or saturation problems that can arise even though preselection and/or filtering is used for survey measurements; and 3) limited man-made noise such as impulsive noise from automobile ignition systems, electrical machinery, and power lines that can add to the received signals of interest and give misleading results.

The primary logistic factors are 1) commercial power to increase the probability of completing the spectrum survey (typically two weeks of 24-hr operation) without power interruptions; 2) commercial telephone for relatively inexpensive reliable communications, compared to the RSMS cellular telephone that possibly could contaminate the measurements when transmitting; and 3) security of personnel, vehicle, and electronic hardware.

The ideal site is a well-illuminated, fenced, and patrolled area that satisfies all of the primary site selection factors above and has reasonable access to lodging for the operating personnel.

A.3 Spectrum Survey Measurements

Spectrum surveys are normally conducted for two weeks using the RSMS in an automatic mode. The measurement system is preprogrammed to continuously run software algorithms tailored to the characteristics of the radio emitters that typically occupy measured frequency sub-bands. Two decades of making such measurements in cities across the United States suggest that general patterns of spectrum occupancy tend to be repeated from site to site. Emissions from the following sources commonly are observed during RSMS spectrum surveys:

- land-mobile, marine-mobile, and air-mobile communication radios;

- terrestrial, marine and airborne radars, and airborne radio altimeters;
- radionavigation emitters, such as TACAN and VOR;
- cellular and trunked communication systems;
- broadcasting transmitters such as UHF and VHF television, and multipoint distribution systems (wireless cable TV);
- industrial, scientific and medical (ISM) sources, including vehicular tracking systems, welders, and microwave ovens; and
- common carrier (point-to-point) microwave signals.

Emissions that are ***not*** normally receivable during spectrum surveys are:

- satellite downlink emissions;
- galactic and solar noise;
- some types of spread spectrum signals; and
- radio transmitters that are turned off.

Although the last category is self-evident, questions exist regarding the extent to which users who have assignments in the radio spectrum either do not operate, or operate very rarely, with those assignments. Appendix B discusses factors related to probability of intercept and addresses matters of measurement time vs. statistical significance of data.

As mentioned above, there are many different types of radio signals within the measurement frequency range. Each is measured with a hardware configuration and measurement algorithm specifically selected to give the most useful description of the particular type of signal(s) expected in a frequency sub-band. The measurement system parameters specially configured for each signal type include: antennas, signal conditioning, tuning speed, measurement bandwidth, detector mode, and measurement repetitions. The RSMS measurement software automatically switches the measurement system to the proper configuration for each sub-band. The measurements are repeated in various sub-bands according to specifications established by consideration of signal intercept probability, signal variability, measurement significance, and expenditure of system resources.

For spectrum surveys, the RSMS normally performs measurements of general spectrum occupancy across a frequency range of 108 MHz to 19.7 GHz. To accomplish this task, measurements are conducted in an automatic mode with the RSMS configured as two measurement systems, identified as "System-1" for frequency measurements below 1 GHz, and "System-2" for simultaneous measurements above 1 GHz.

The data acquisition (DA) measurement software[1] provides instructions to configure each receiver system, execute measurement routines, record measured data, and maintain a real-time log of the measurements and key parameters. The measurement system configuration parameters used by the software are called "band events" and the automated band event execution procedures are called "band event schedules." Unattended operation of the measurement system for extended periods of time is made possible through this use of computer control. Remote monitoring and control of the RSMS is possible via a telephone modem linked to the computer. Standardized measurement band event schedules are used for each spectrum survey, with the measured data stored for postmeasurement processing.

A.3.1 Survey Band Events

The spectrum measured by the RSMS is divided into selected frequency ranges (survey bands) that are measured according to a computer-stored list of measurement parameters and instrument settings called a band event. Each band event combines a measurement algorithm with a particular set of signal input ports, front-end configurations, spectrum analyzer modes and settings, and data-recording options. Band event parameters and options are detailed in Appendix D. The factors considered when selecting frequency sub-bands, receiver algorithms, and other parameters for the band events are discussed in Appendix B. Spectrum survey "standard" band events for System-1 and System-2 are shown in Tables A-1 and A-2, respectively.

Each row in the survey band event tables, beginning with an event number, shows the measurement parameters for a specific receiver configuration in the RSMS. Instruction to run the event can be entered by an operator or come from a computer-loaded band event schedule, as explained in Section A.3.2. The DA software, when instructed, sends the command parameters for an event to the system hardware and initiates measurements for the event. Tables A-1 and A-2 are subdivided into four parts: 1) "Standard Events" identifies the event number and exact frequency range of interest, 2) "DA Receiver Parameters" shows input values for receiver configuration subroutines, 3) "DA Spectrum Analyzer Parameters" lists configuration command values sent to the spectrum analyzer, and 4) "Antenna" identifies the type and gain of the antenna selected for the event. Appendix D contains operational descriptions for all of the table parameters found under 2) and 3) above.

[1]All automated measurements are accomplished through computer software control of the measurement hardware. Appendix D contains a complete description of the RSMS data acquisition software.

Table A-1. Standard Spectrum Survey Band Events for RSMS System-1

Standard Events		DA Receiver Parameters						DA Spectrum Analyzer Parameters*						Antenna**	
Event Number	Freq. Band (MHz)	Algor-ithm	Start (MHz)	End (MHz)	Scans (# of)	Sweeps (# of)	Steps (# of)	IFBW (kHz)	Detector Type	VBW (kHz)	RL (dBm)	MH/VA (#swps)	Swp/stp (sec)	Type	Gain (dBi)
11	108-162	sw/m3	104	164	6	100	1	10	sample	10	-20	1	0.3	omni	-5
12	162-174	sw/m3	160	180	2	500	1	10	sample	10	-20	1	0.3	omni	-2
13	174-216	sw/m3	170	220	1	500	1	100	sample	100	-10	1	0.02	omni	0.7
14	216-225	sw/m3	216	225	3	60	1	3	sample	3	-30	1	0.9	omni	1.0
15	225-400	sw/m3	225	405	6	100	1	30	sample	30	-10	1	0.09	omni	1.5
16	400-406	sw/m3	400	406	2	60	1	3	sample	3	-10	1	0.9	omni	2.9
17	406-420	sw/m3	400	420	2	200	1	10	sample	10	-20	1	0.9	omni	2.8
18	420-450	stepped	420	450	1	1	30	1000	+peak	3000	-10	1	12	omni	2.5
19	450-470	sw/m3	450	470	2	200	1	10	sample	10	-20	1	0.9	omni	2.3
20	470-512	sw/m3	470	520	5	100	1	10	sample	10	-20	1	0.9	omni	2.0
21	512-806	sw/m3	512	812	3	200	1	100	sample	100	-10	1	0.02	omni	2.6
22	806-902	sw/m3	806	906	10	60	1	10	sample	10	-20	1	0.3	omni	1.4
23	902-928	swept	900	930	3	1	1	10	MXMH	10	-10	600	0.3	omni	0.9
24	902-928	stepped	900	930	1	1	30	1000	+peak	3000	-10	1	12	omni	0.9
25	928-960	sw/m3	920	960	4	300	1	10	sample	10	-20	1	0.3	omni	0.9

* For spectrum surveys, attenuation is set to 0 (default), display to 10 dB/div, and the spectrum analyzer in use must measure at least 1000 points per scan.

** A 100-MHz to 1-GHz omnidirectional antenna is used for spectrum surveys. For the Los Angeles survey, however, a 100-MHz to 1-GHz log periodic antenna (LPA) with 5.5- to 6.1-dBi gain was used. The LPA was mounted at a 45ß angle to emulate slant polarization (see Section 2.3)

Table A-2. Standard Spectrum Survey Band Events for RSMS System-2

Standard Events		DA Receiver Parameters						DA Spectrum Analyzer Parameters*						Antenna**	
Event Number	Freq. Band (MHz)	Algor-ithm	Start (MHz)	End (MHz)	Scans (# of)	Sweeps (# of)	Steps (# of)	IFBW (kHz)	Detector Type	VBW (kHz)	RL (dBm)	MH/VA (#swps)	Swp/stp (sec)	Type	Gain (dBi)
05	960-1215	sw/m3	950	1250	1	500	1	300	+peak	3000	-10	1	0.02	omni	2.1
06	1215-1400	stepped	1200	1400	1	1	200	1000	+peak	3000	-10	1	12	omni	2.2
07	1350-1400	sw/m3	1350	1400	5	100	1	10	sample	10	-20	1	0.3	omni	2.2
08	1400-1530	sw/m3	1400	1550	5	200	1	30	sample	30	-10	1	0.09	omni	2.2
09	1530-1710	sw/m3	1530	1710	6	500	1	30	sample	30	-10	1	0.09	omni	2.2
10	1710-2300	swept	1700	2300	6	1	1	100	MXMH	100	-10	600	0.1	dish	17.5
11	2300-2500	swept	2300	2500	2	1	1	100	MXMH	100	-10	600	0.1	omni	2.5
12	2500-2700	swept	2500	2700	2	1	1	100	MXMH	100	-10	600	0.1	dish	19.8
13	2700-2900	stepped	2700	2900	1	1	200	1000	+peak	3000	-10	1	5^{+}	omni	2.8
14	2900-3100	stepped	2900	3100	1	1	200	1000	+peak	3000	-10	1	12	omni	2.8
15	3100-3700	stepped	3100	3700	1	1	200	3000	+peak	3000	-10	1	12	omni	3.0
16	3700-4200	swept	3700	4200	5	1	1	100	MXMH	100	-10	600	0.1	dish	23.5
17	4200-4400	sw/m3	4200	4400	1	500	1	300	+peak	3000	-10	1	0.02	omni	3.0
18	4400-5000	swept	4400	5000	6	1	1	100	MXMH	100	-10	600	0.1	dish	25
19	5000-5250	sw/m3	5000	5300	1	500	1	300	+peak	3000	-10	1	0.02	omni	3.1
20	5250-5925	stepped	5250	5950	1	1	240	3000	+peak	3000	-10	1	12	omni	3.1

Table A-2. Standard Spectrum Survey Band Events for RSMS System-2 (Continued)

Standard Events		DA Receiver Parameters						DA Spectrum Analyzer Parameters*						Antenna**	
Event Number	Freq. Band (MHz)	Algor-ithm	Start (MHz)	End (MHz)	Scans (# of)	Sweeps (# of)	Steps (# of)	IFBW (kHz)	Detector Type	VBW (kHz)	RL (dBm)	MH/VA (#swps)	Swp/stp (sec)	Type	Gain (dBi)
21	5925-7125	swept	5925	7125	4	1	1	300	MXMH	1000	-10	600	0.1	dish	28
22	7125-8500	swept	7100	8600	5	1	1	300	MXMH	1000	-10	600	0.1	dish	30
23	8500-10550	stepped	8500	10600	1	1	720	3000	+peak	3000	-10	1	4	omni	3.1
24	10550-13250	swept	10550	13250	1	1	1	3000	MXMH	3000	-10	600	0.1	dish	33
25	13250-14200	stepped	13250	14250	1	1	340	3000	+peak	3000	-10	1	4	omni	2.8
26	14200-15700	swept	14200	15700	1	1	1	3000	MXMH	3000	-10	600	0.1	dish	35
27	15700-17700	stepped	15700	17700	1	1	700	3000	+peak	3000	-10	1	4	omni	2.7
28	17700-19700	swept	17700	19700	1	1	1	3000	MXMH	3000	-10	600	0.1	dish	37

* For spectrum surveys, attenuation is set to 0 (default), display to 10 dB/div, and the spectrum analyzer in use must measure at least 1000 points per scan.

** A 500-MHz to 18-GHz slant polarized biconical omnidirectional antenna is used for spectrum survey measurements. A parabolic reflector (dish) antenna is used for azimuth-scanning. See Sections C.4 and D.2 of Appendices C and D, respectively, for descriptions of the antennas and the swept/azimuth-scanning algorithm used with the dish antenna.

\+ If slow-rotation emitters (e.g., weather radars) contribute significantly to the measured occupancy in a survey band, an increased step time (dwell) may be used to better characterize their peak power envelope (see Section B.7.2 in Appendix B).

A.3.2 Band Event Schedules

Using RSMS measurement control software, any band event can be executed by an operator at any time. For spectrum surveys, many band events are used to span several gigahertz of spectrum and each event requires a different amount of time to execute. DA software includes an automated band event execution mode where any of the band events may be programmed (scheduled) to execute in any sequence for any amount of time (within hardware limits on continuous operation of the measurement system).

There are two types of schedules used for spectrum surveys with the RSMS: a standard band event schedule of all the survey bands, or a special band event schedule for a few selected survey bands. For example, if a survey was conducted in a port city, a special schedule might include only survey bands with assignments for maritime communications (this was not, however, the case for Los Angeles). Any number of special schedules can be run during a survey.

Tables A-3 and A-4 show the standard band event schedules for RSMS System-1 and System-2, respectively. Tables A-5 and A-6 show special band event schedules for measurements in survey bands expected to show altered usage during adverse weather. The tables include: 1) schedule number;[2] 2) band event number (specifies which band event to execute in the sequence); 3) priority number (value assigned to the band event data, with "1" being the highest priority); 4) event time (approximate time in minutes needed to run the event); and 5) accumulative time (approximate time in hours that the schedule has run).

Band event priority is an important consideration when scheduling standard band events; i.e., some frequency bands in a spectrum survey are of more interest to spectrum managers than others. In fact, an important part of the preparation for a spectrum survey is a review of local frequency assignments and allocations. From this preliminary information, measurement parameters may be modified and band event priority numbers (1, 2, or 3, with 1 being highest priority) adjusted to optimize survey data.

Highly dynamic bands (where occupancy changes rapidly) include those used by mobile radios (land, marine, and airborne) and airborne radars. These bands are assigned a high priority and are measured often during a spectrum survey in order to maximize opportunities for signal detection. Bands that are not very dynamic in their occupancy (such as those occupied by commercial radio and television signals or fixed emitters such as air traffic control radars) need not be observed as often, because the same basic occupancy picture will be generated every time. Such bands are given a low priority and less measurement time. An extreme case is that of the common carrier bands, which are essentially nondynamic. Generally, these are only measured once during a survey and are not included in the band event schedules.

---

[2]Schedule numbers are assigned sequentially from 1 to 64. The system software supports only 64 band events in a schedule; however, there is no limit on how many times the schedule executes during a survey.

Table A-3. Standard Band Event Schedule for RSMS System-1

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	12	1	16.3	0.27
2	11	2	10.3	0.44
3	17	1	10.8	0.62
4	14	2	5.1	0.71
5	13	3	5.8	0.81
6	19	1	10.8	0.99
7	22	2	10.8	1.17
8	20	1	13.8	1.40
9	23	2	5.3	1.48
10	25	1	20.0	1.82
11	18	2	6.7	1.93
12	12	1	16.3	2.20
13	16	3	3.4	2.26
14	17	1	10.8	2.44
15	24	2	6.7	2.55
16	19	1	10.8	2.73
17	11	2	10.3	2.90
18	20	1	13.8	3.13
19	14	2	5.1	3.22
20	25	1	20.0	3.55
21	21	3	7.3	3.67
22	12	1	16.3	3.94
23	22	2	10.8	4.12
24	17	1	10.8	4.30
25	23	2	5.3	4.39
26	15	3	8.3	4.53
27	19	1	10.8	4.71
28	18	2	6.7	4.82
29	20	1	13.8	5.05
30	24	2	6.7	5.16
31	25	1	20.0	5.50

Table A-4. Standard Band Event Schedule for RSMS System-2

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	05	3	5.6	0.09
2	06	3	42.0	0.79
3	07	2	8.6	0.94
4	08	2	12.7	1.15
5	09	1	37.2	1.77
6	11	3	3.0	1.82
7	13	3	18.0	2.12
8	14	2	42.0	2.82
9	15	2	42.0	3.52
10	17	3	5.6	3.61
11	19	3	5.6	3.71
12	20	2	49.0	4.52
13	23	2	49.0	5.34
14	25	1	25.0	5.76
15	27	1	52.0	6.62
16	05	3	5.6	6.72
17	09	1	37.2	7.34
18	17	3	5.6	7.43
19	19	3	5.6	7.52
20	25	1	25.0	7.94
21	27	1	52.0	8.81
22	05	3	5.6	8.90
23	07	2	8.6	9.04
24	08	2	12.7	9.25
25	09	1	37.2	9.87
26	11	3	3.0	9.92
27	14	2	42.0	10.62
28	15	2	42.0	11.32
29	17	3	5.6	11.42
30	19	3	5.6	11.51

Table A-5. Adverse Weather Band Event Schedule for RSMS System-1

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	12	1	16.3	0.27
2	11	2	10.3	0.44
3	12	1	16.3	0.72
4	14	2	5.1	0.80

Table A-6. Adverse Weather Band Event Schedule for RSMS System-2

Schedule Number	Band Event Number	Priority Number	Event Time (minutes)	Accumulative Time (hours)
1	09	1	37.2	0.62
2	23	2	49.0	1.44
3	05	3	5.6	1.53
4	17	3	5.6	1.62
5	20	2	49.0	2.44
6	14	2	42.0	3.14
7	13	3	18.0	3.44

The standard band event schedules are usually arranged to execute priority 1 events three times more often than priority 3 events. However, some adjustment to this arrangement may be necessary to accommodate total time required to complete the sequenced band event schedule. For example, if less than two weeks of measurement time were available, a time-consuming priority 1 event (such as Band Event 27 in Table A-4) might not be run three times as often as priority 3 events to ensure that all bands would be measured.

Because of the many land mobile radio (LMR) bands below 1 GHz, System-1 scheduling reflects some preplanning for time-of-day analysis. The sequenced schedule is prepared so that all events will be run within an 8-hr period; such that, after a few days of 24-hr data collection certain LMR bands will be measured at least once during each hour.